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RESEARCH ON THE PREFERRED INDICATORS OF INORGANIC COMPONENTS OF MODIFIED BASALT FIBERS

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Abstract. *This article presents the results of studies of modified basalt crystalline fibers coated with resinous chemicals and after hardening, which are used to manufacture fire-resistant fabric and for sewing fire-protective clothing. The results of the study recommended in this article prove the possibility of expanding the scope of application of previously modified basalt crystalline fibers coated with resinous chemicals by increasing the strength of the threads through the use of a new method carried out with minimal technological costs.*

Keywords: *basalt, thermodynamics, heating, pyroxene, crystalline fiber, filtering material, fiber, melting, dry processing.*

ИССЛЕДОВАНИЕ ПРЕДПОЧТИТЕЛЬНЫХ ПОКАЗАТЕЛЕЙ НЕОРГАНИЧЕСКИХ КОМПОНЕНТОВ МОДИФИЦИРОВАННЫХ БАЗАЛЬТОВЫХ ВОЛОКОН

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Аннотация. *В данной статье изложены результаты исследований модифицированных базальтовых кристаллических нитей, покрытых смолистыми химическими веществами и после упрочнения, которых используют для изготовления огнеупорной ткани и предназначенных для пошива огнезащитной одежды и легких фильтров механической очистки. Рекомендованные в данной статье результаты исследования доказывают возможности расширить область применения базальтовых кристаллических волокон покрытых смолистыми химическими веществами, путем повышения прочности нитей за счет использования нового способа осуществляемый с минимальными технологическими затратами.*

Ключевые слова: *базальт, термодинамика, нагрев, пироксен, кристаллическое волокно, фильтрующий материал, волокно, плавление, сухая обработка.*

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MODIFIKATSIYALANGAN BAZALT TOLALARINING NOORGANIK KOMPONENTLARINING AFZALLIK KO‘RSATKICHLARI BO‘YICHA TADQIQOTLAR

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Annotatsiya. *Ushbu maqolada olovbardosh matolar tayyorlash uchun ishlatiladigan va olovbardosh kiyimlar va yengil mexanik tozalash filtrlari tikish uchun mo‘ljallangan qatronli kimyoviy moddalar bilan qoplangan va mustahkamlangan modifikatsiyalangan bazalt kristall iplarini o‘rganish natijalari keltirilgan. Ushbu maqolada tavsiya etilgan tadqiqot natijalari minimal texnologik xarajatlar bilan amalga oshiriladigan yangi usulni qo‘llash orqali iplarning mustahkamligini oshirish orqali smolasimon kimyoviy moddalar bilan qoplangan bazalt kristall tolalarining qo‘llanilish sohasini kengaytirish imkoniyatlarini isbotlaydi.*

Kalit so‘zlar. *bazalt, termodinamika, qizdirish, piroksen, kristall tola, filtrlovchi material, tola, suyuqlantirish, quruq ishlov berish.*

Introduction. High-temperature processing of basalt rocks through melting was conducted in smelting furnaces, whose operations are controlled using computer technology. The analysis and calculation of technological or other operational parameters are managed, processed, and analyzed with the help of computer programs. The melting temperature of basalt rocks ranges from 1200 to 1600°C, depending on various parameters (literature: dissertations by A. Kurbanov and L. Sattorov), chemical properties, and the source of the basalt. Therefore, all calculations for the thermal treatment of basalts were performed in an electric arc furnace at a pressure of 1 atm, within a temperature range of 400 to 2000°C, taking into account the erosion of graphite electrodes (C = 2%).

Methods. To determine changes in inorganic substances in basalts, the method of infrared spectroscopy was used, which allowed for the investigation of the structural features of various inorganic compounds. Samples of the rock were prepared in the form of tablets, which were then placed in the IR Tracer 100 SHIMADZU device within the wavelength range of 400 to 4000 cm^{-1}. After that, infrared spectra were recorded. One of the obtained spectra is presented in Figure 1.

Figure 1 shows the graph of spectra for natural radioactive nuclides in the basalt deposit “Aydarkul”. In the rock samples from the “Asmansai” deposit, unlike those from “Aydarkul”, elevated levels of thorium (232Th) were found. In the studied basalts, the total gamma activity of naturally radioactive elements did not exceed 370 Bq/kg.

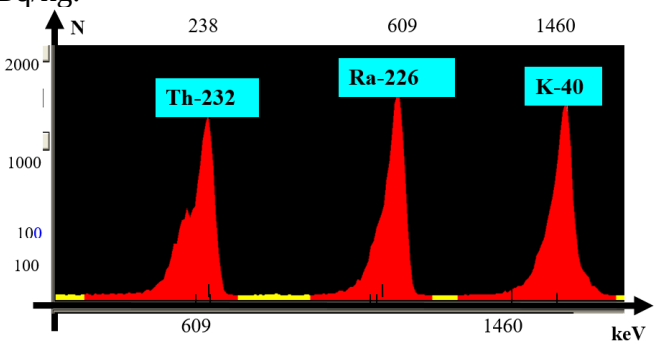

Figure 1. Gamma spectra of natural radioactive nuclides showing the energy output of radionuclides: sample No. 1, deposit “Aydarkul”.

Research has established that the content of naturally radioactive elements complies with sanitary standards (SanPIN-00193-06), and the basalts primarily consist of silicates: pyroxene, olivine, and plagioclase. The percentage content of these minerals affects the chemical, physical, mechanical, technological, and other characteristic indicators, as well as the costs associated with processing this rock.

To study the interaction of various silicate compounds in the basalts of the “Aydarkul” deposit,

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the following reagents were used:

a) Acids - HCl, H_2SO_4, HNO_3;

b) Bases - NaOH, $Ca(OH)_2$;

c) Salts - $AgNO_3$, $BaCl_2$, $CaCl_2$, $K_4[Fe(CN)_6]$.

To obtain suspensions necessary for the study, 10 g of basalt was randomly selected. The mass was then mixed with distilled water to form a solution. The suspension formation was allowed to continue for 30 minutes. After this, the suspension was filtered.

In this process, the solution was considered colloidal, acquiring a pale yellow color. It was then poured into another container and further filtered through a Büchner funnel (designed for filtering solutions) and decanted several times with distilled water. The second portion of the precipitate was similarly filtered and washed with water. The precipitate was dried in an oven at a temperature of 60 to 70°C. Simultaneously, some qualitative reactions with the filtrate for ions such as Na^+, Mg^{2+}, Ca^{2+}, Fe^{2+}, etc., were conducted.

It is important to note the results of the study. The derivative graphical analysis allowed for the determination that conducting experiments under similar or identical conditions helps obtain comparative data on the reactivity of calcium, lithium, sodium, and potassium carbonates when interacting with iron oxide, depending on the ratio of the mixture components and the experimental conditions regarding basalt's inorganic constituents.

In mixtures of alkali metal carbonates with iron oxide, metafaerite is initially formed regardless of the component ratios, existing as the sole compound within a specific temperature range.

The practical significance of the derivative gram analysis of samples, which were recorded on a synchronous thermogravimetric derivative graph (LabSysEvo, Seta ram, France) up to 1400°C, is noteworthy. The mass of the finely ground sample was 150-200 mg, and the heating rate was 10°C/min. The mass loss during the heating of the sample to 1400°C was 20.61%.

Further temperature increases were accompanied by the combustion of organic materials and dehydration of mineral impurities. A broad, shallow endothermic effect observed between 330-775°C is attributed to the overlapping effects of polymorphic transformations of quartz and the onset of decarbonization of calcium minerals. The rate of mass loss significantly increases in the decomposition range of carbonate minerals from 775-935°C, with a mass loss of up to 13.11%, mainly reflecting the intensive decomposition of calcite.

It is important to note that the most significant property of basalt fiber is its melting point of 1450°C, which is considerably higher than that of glass fiber and approaches the melting point of ceramic fiber. At the same time, basalt fiber is significantly cheaper than ceramic fiber. The operating temperature range for basalt fiber varies from -260 to +700°C, whereas glass fiber is used within a temperature range of -50 to +380°C. Basalt fibers exhibit high chemical resistance to moisture, salt solutions, and both acidic and alkaline environments, as confirmed by the studies presented in this dissertation.

Basalt fiber materials are non-combustible and do not emit harmful gases at high temperatures. The thermal conductivity coefficient of basalt wool is approximately 0.05 $W \cdot m^{-1}K^{-1}$, which is only twice as high as the thermal conductivity of air at room temperature. The low specific weight of basalt wool products allows them to compete with foam concrete in terms of insulation efficiency. The primary raw material for producing basalt fiber is magmatic rock from ancient volcanic processes, which has solidified in the upper layers of the Earth's crust or on the surface. This includes basalts, gabbros, and diabases, which are widely available and practically inexhaustible.

Mineral wools are made from basalt fiber, which is categorized into two groups: discrete (or staple) fibers, with lengths ranging from a few millimeters to several tens of centimeters, and continuous fibers (one strand extending several kilometers). For insulation production, staple fibers of fine diameter (Ø = 200-400 μm) and super-fine fibers with diameters of 300 μm or less are used. In the EU, most mineral fibers are produced with diameters ranging from 400 to 600 μm. Fibers thicker than 10 μm can penetrate human skin.

Since ceramic and carbon fibers are significantly more expensive than basalt fiber, continuous basalt fiber will find wide applications in composite construction materials as an additive in concrete, tiles, paving stones, asphalt, railway sleepers, and other products where only a minimal

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reinforcing additive is required in large volumes. Additionally, basalt fibers can be directly used in the manufacture of exceptionally durable automotive brake pads and linings, which can last as long as the vehicle itself. Chemical modifications of its surface allow it to be used as cord for automotive tires and in the production of bulletproof vests, replacing Kevlar fabric.

Chemical treatment of the surface of crystalline fibers allows for a direct bond between basalt and epoxy resins, enabling the formation of threads through spinning, as well as with other polymer systems. This is particularly effective in the production of basalt plastic reinforcement, various construction profiles, pipes, and nets. Continuous basalt fibers are confidently and objectively displacing glass fibers in the overwhelming majority of market segments. The main, and practically the only, limiting factor for the widespread application and distribution of basalt fibers and products today is the extremely low volume of their actual industrial production.

Thermodynamic Analysis of Heating and Melting of Basalt.

To determine the optimal parameters for the processing technology of basalt minerals through thermal treatment, thermodynamic calculations of the heating and melting process in an electromagnetic reactor were conducted. The electromagnetic reactor is a thermally insulated system, with the lining provided by a natural layer of soot, generated during the reactor's operation from the melt layer adjacent to the water-cooled walls. Therefore, the calculations of the melting process of basalts in this reactor are of particular interest, as thermodynamic methods can be applied.

Computer programs for calculating parameters were used in the thermodynamic analysis of high-temperature processes involving melting. It is known that in Uzbekistan, the melting temperature of basalt rocks ranges from 1500 to 1600°C. Consequently, taking into account that the electromagnetic reactor is not airtight, all calculations for the melting of basalt were performed at a pressure of 1 atm.

There is information regarding changes in the inherent and material properties of basalt rocks during mechanical processing, which is carried out through dry processing methods such as crushing, grinding, classification, sieving, pressing, and drying of the semi-finished product. However, it has been established that the analyzed data contains information about changes in the inherent properties of basalts due to thermal treatment. The first indicator is the alteration of the external shades of the raw material after thermal treatment of the crushed material.

In such cases, the specific characteristics of the crushed mass of the examined rock become particularly evident. In this instance, basalt can undergo phase changes in chemical composition, structural restoration, and alterations in the properties of the liquid or solid phases of the raw material. To determine changes in the inorganic substances in basalts, the method of infrared (IR) spectroscopy was employed, which allowed for the investigation of the structural features of various inorganic compounds present in the basalts of the Kyzylkum region.

The method is based on the phenomenon of absorption of electromagnetic radiation in the infrared range by groups of atoms in the tested object. This absorption is associated with the excitation of molecular vibrations by quanta of infrared light. The IR spectra of the "Aydarkul" basalts are presented in Figure 2. Based on the results of infrared spectroscopy, a chemically reliable method for analyzing the thermal treatment process of basalts can be developed.

To this end, samples of the rock were prepared in the form of tablets and subsequently placed in the IR Tracer 100 SHIMADZU device within the wavelength range of 400 to 4000 cm^{-1}. The IR spectra were then recorded. The resulting spectrum is presented in Figure 2. For studying the interaction of various silicate compounds in the basalts of the “Aydarkul” deposit, the reagents noted in the methodology were used.

Overall, to obtain sufficient information regarding the mutual transformations of basalts during thermal treatment, the IR spectroscopy method was utilized. It was found that this action should be performed prior to thermal treatment.

Results. As a result of analyzing the obtained research data, it was established that absorption bands are noticeable in the IR spectra. Such bands can be particularly observed in the range of 756 to 800 cm^{-1}, corresponding to the deformation vib-

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ration of the M–O bond (where M is a metal) in the -CO_3 groups, which may disappear during thermal treatment at 900°C, as confirmed by the subsequent decomposition of the carbonates.

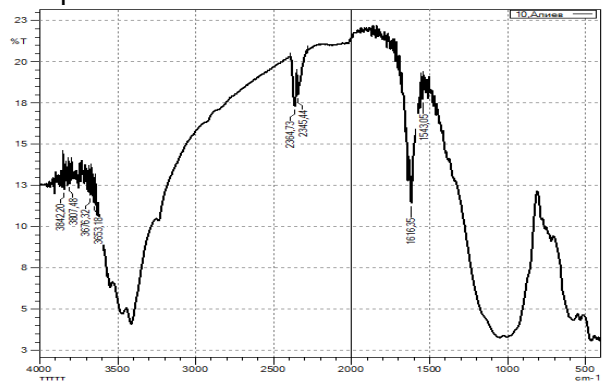

Figure 2. IR Spectra of "Aydarkul" Basalts.

Absorption bands in the region around 1000 cm^{-1} reveal a broad spectrum associated with the group ν(CO)Pr, -OH, and ν(-SiO). Absorption bands at 1639 and 1620 cm^{-1} correspond to the deformation vibrations δ(H_2O), and in the spectra post-treatment, their intensity becomes shorter. In the regions of 3400 and 3600 cm^{-1}, the absorption bands correspond to OH groups of water and residues of mineral acids such as $[CO_4]^{2-}$, $[SiO_4]^{2-}$, and [-$Al(OH)_4$]. Thus, it has been established that during the thermal treatment of the "Aydarkul" basalts, there is a change in the mineralogical composition, which can affect the technological processing of the raw material.

Overall, physicochemical analyses show that the initial samples of the "Aydarkul" basalts contain impurities of various carbonates, metals, hygroscopic water, and crystallized water, which are completely removed from the basalt composition during thermal treatment at temperatures of 480 and 580°C.

Based on the above, it is recommended that prior to processing the raw material, the basalt rock be purified of sludge, clay impurities, and hydroxides. This necessity arose during the conducted research and is justified by the attempt to enhance the quality indicators of the raw material through the purification of the rock. Such statements are grounded in the need to remove sludge, clay impurities, and hydroxides that have penetrated into the minerals due to prolonged exposure, negatively affecting their quality. Therefore, a study of the structural changes in basalt minerals was conducted.

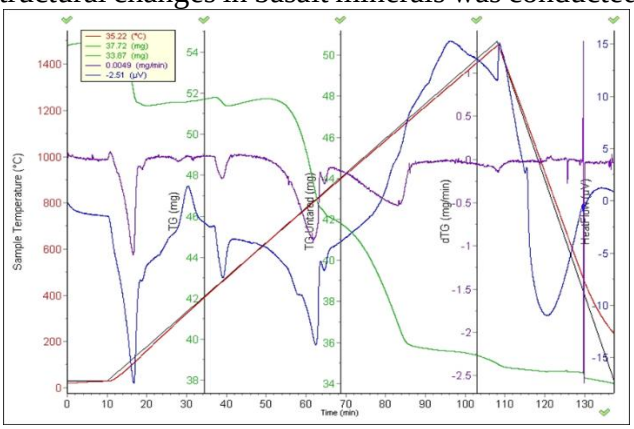

Figure 3. Derivative Thermogram of Thermal Treatment Results for "Asmansai" Basalt Samples.

The study of structural changes in basalts was performed through further examination of the thermal treatment of the rock, relying on their characteristic indicators. The process of thermal impact on the basalts, where transformations of the basalt rock occur, is expressed in the derivative thermogram presented in Figure 3. In this study, the Labybsys IVO device was used, with heating temperatures ranging from 500°C to 1200°C, and a heating rate of 5°C/min.

Based on the results obtained from the derivative thermogram, the samples were subjected to thermal treatment at temperatures of 100, 300, 500, 700, 900, 1000, and 1200°C. A muffle furnace was used for thermal treatment. The endothermic effects of the pyrolysis process were observed to occur at temperatures between 80 and 240°C.

The removal of hygroscopic water contained in the rocks is of significant practical importance as it directly affects the thermal treatment process. For instance, at a temperature of 520°C, a decrease in the effects can be observed, along with slight increases in the mass of the object under study, which corresponds to the mutual transformations of the components of the basalts. However, when the temperature reaches 820°C, pronounced endothermic effects are observed, resulting in mass losses of up to 16 mg from the randomly selected sample mass (approximately 37.72% of the total mass), which aligns with the decomposition of carbonates and silicates present in the basalt rocks.

The structure and glassy form of crystalline

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fibers, as well as their properties, are closely related to the cooling rate of the basalt melt. Therefore, the temperature of the melt is maintained with additional heated air after it exits the die. As the basalt melt cools, the rapid increase in viscosity and decrease in temperature cause the thermal motion of the particles to freeze.

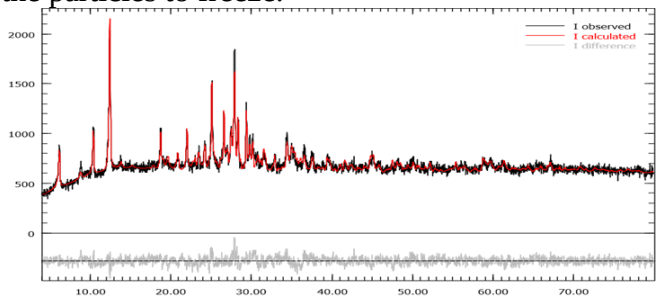

Figure 4. Results of X-ray Diffraction Analysis.

The examination of the X-ray diffractograms presented in Figure 4 reveals distinct peaks that define the crystalline structure of the initial material. The monotony of the diffractogram for the basalt fiber demonstrates that a certain structure is maintained in the melt for silicate compounds and melts, determined by the corresponding silicate chains.

It has been established that during the thermal treatment of basalts from the "Aydarkul" deposit, thermal decomposition of silicates, alumino-silicates, and carbonates occurs. It is noted that during thermal processing, the silicate components of the basalts—pyroxenes, olivines, and plagioclases—also undergo structural changes, resulting in the formation of transformation products.

Moreover, it is important to highlight that the variations in the ratios of chemical elements in basalts can significantly influence their strength, chemical resistance, alkalinity resistance, as well as melting temperatures and other physical and mechanical properties of the modified fibers. This indicates that modified fibers can help determine the intended use and specified parameters of basalt fiber-based crystalline modified filtering materials.

Notably, a distinct relationship has been observed between oxygen and elements such as Al, Fe, Mg, K, N, Ti, and Si. It has been identified that the multi-component melts of basaltic rock are ion-molecular microheterogeneous substances formed from a combination of organic compounds in the presence of oxygen and anionic complexes. The microheterogeneity of the molten mass is distributed among cations, with stronger cations (like Fe^{2+}) surrounding O^{2+}, while weaker cations (like Ca^{2+}) group with anions such as Si_2O_4.

Conclusions. It has been established that during the thermal treatment of basalts from the “Aydarkul” deposit, thermal decomposition of silicates, aluminosilicates, and carbonates occurs. During this process, the silicate components of the basalts—pyroxenes, olivines, and plagioclases-also undergo structural changes, resulting in the formation of transformation products.

However, it is not possible to destroy the structure of modified fibers coated with resinous chemicals, which protect them from external influences. The preserved structure allows for chemical interactions with the fibers, which are covered by modification layers, facilitating chemical decomposition within the resin coating. This enables experimental studies to determine and clarify the physical and mechanical properties to define the application area of the newly modified fibers.

Thus, the research into the predominant indicators of the inorganic components of modified basalt fibers has shown the feasibility of additional modification, allowing for an expanded range of applications, particularly as filtering materials.

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